



Distal extension of the direct anterior approach to the hip poses risk to neurovascular structures: an anatomical study

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Abstract: Background: The anterior approach to the hip gained popularity for total hip arthroplasty in recent years. Distal extension of the anterior approach, sometimes needed intraoperatively, potentially endangers neurovascular structures to the quadriceps. The aim of this study was to determine the anatomical structures placed at risk by distal extension of the anterior approach to the hip. Methods: Seventeen cadaveric hemipelves from twelve human specimens were dissected. The femoral nerve and its branches and the vessels arising from the lateral femoral circumflex artery were assessed in relation to the distal extension of the anterior approach. The damage caused by the introduction of a cerclage cable passer was also investigated. Results: The area immediately distal to the intertrochanteric line is a common entry point for several nerve branches and is a useful distal landmark for surgeons to use to protect important neurovascular structures. The distal extension of the anterior approach compromises the nerve supply to the anterolateral portions of the quadriceps. Introduction of a cerclage cable passer through the anterior access also jeopardizes nerve branches to the vastus lateralis, lateral parts of the vastus intermedius, and branches of the lateral femoral circumflex artery. Conclusions: Distal extension of the direct anterior approach to the hip is challenging to accomplish without neurovascular injury to anterolateral parts of the quadriceps muscle group. In addition, important neurovascular structures are endangered with the introduction of a cable passer through the anterior approach. Clinical Relevance: Distal extension of the direct anterior approach to the hip beyond the intertrochanteric line may compromise neurovascular structures supplying the quadriceps muscle. The direct anterior approach for total hip arthroplasty has recently gained popularity with good clinical results. However, there have been reports of intraoperative complications, such as femoral fracture, implant failure, and muscle trauma⁷⁻¹², that may require an extension of the surgical approach. Kennon et al.¹ reported that the direct anterior approach could be safely extended proximally and distally even in complex revisions without clinically relevant nerve injuries. Furthermore, a textbook on surgical exposures describes and recommends this option¹³. While proximal extension with detachment of the tensor fascia femoris and gluteal muscles from the pelvis is part of the Smith-Petersen approach, distal extension could endanger neurovascular structures. The anatomical relationship of nerve branches and blood vessels to the quadriceps with respect to the anterior approach has not been documented, to our knowledge. The purpose of this cadaver study was to demonstrate the neurovascular structures encountered during the direct anterior approach to the hip joint with special emphasis on potential distal extension or the placement of a cerclage cable passer around the proximal part of the femur.

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Distal Extension of the Direct Anterior Approach to the Hip Poses Risk to Neurovascular Structures

An Anatomical Study

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Background: The anterior approach to the hip gained popularity for total hip arthroplasty in recent years. Distal extension of the anterior approach, sometimes needed intraoperatively, potentially endangers neurovascular structures to the quadriceps. The aim of this study was to determine the anatomical structures placed at risk by distal extension of the anterior approach to the hip.

Methods: Seventeen cadaveric hemipelves from twelve human specimens were dissected. The femoral nerve and its branches and the vessels arising from the lateral femoral circumflex artery were assessed in relation to the distal extension of the anterior approach. The damage caused by the introduction of a cerclage cable passer was also investigated.

Results: The area immediately distal to the intertrochanteric line is a common entry point for several nerve branches and is a useful distal landmark for surgeons to use to protect important neurovascular structures. The distal extension of the anterior approach compromises the nerve supply to the anterolateral portions of the quadriceps. Introduction of a cerclage cable passer through the anterior access also jeopardizes nerve branches to the vastus lateralis, lateral parts of the vastus intermedius, and branches of the lateral femoral circumflex artery.

Conclusions: Distal extension of the direct anterior approach to the hip is challenging to accomplish without neurovascular injury to anterolateral parts of the quadriceps muscle group. In addition, important neurovascular structures are endangered with the introduction of a cable passer through the anterior approach.

Clinical Relevance: Distal extension of the direct anterior approach to the hip beyond the intertrochanteric line may compromise neurovascular structures supplying the quadriceps muscle.

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The direct anterior approach for total hip arthroplasty has recently gained popularity with good clinical results¹⁻⁶. However, there have been reports of intraoperative complications, such as femoral fracture, implant failure, and muscle trauma⁷⁻¹², that may require an extension of the surgical approach. Kennon et al.¹ reported that the direct anterior approach could be safely extended proximally and distally even in complex revisions without clinically relevant

nerve injuries. Furthermore, a textbook on surgical exposures describes and recommends this option¹³.

While proximal extension with detachment of the tensor fascia femoris and gluteal muscles from the pelvis is part of the Smith-Petersen approach, distal extension could endanger neurovascular structures. The anatomical relationship of nerve branches and blood vessels to the quadriceps with respect to the anterior approach has not been documented, to our knowledge.

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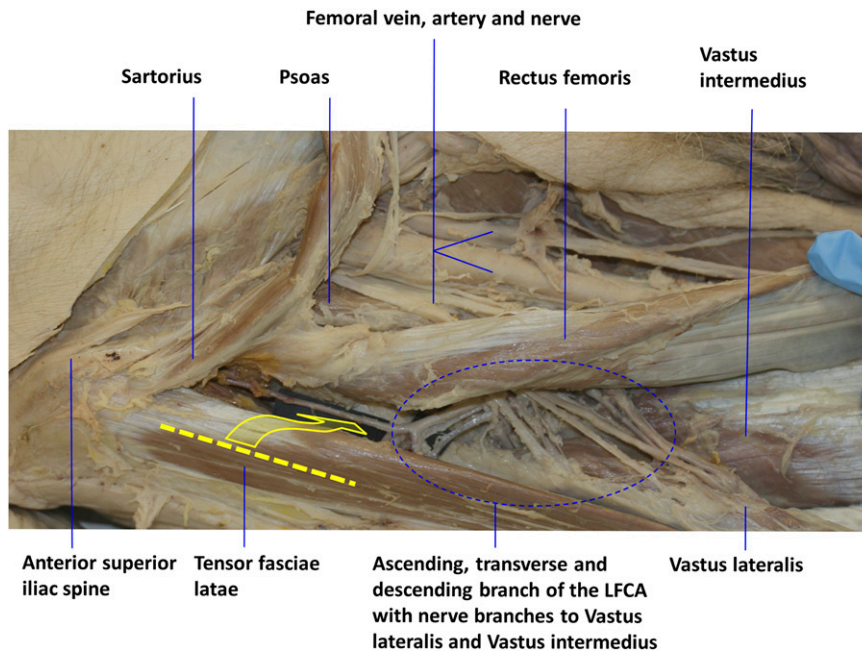


Fig. 1-A

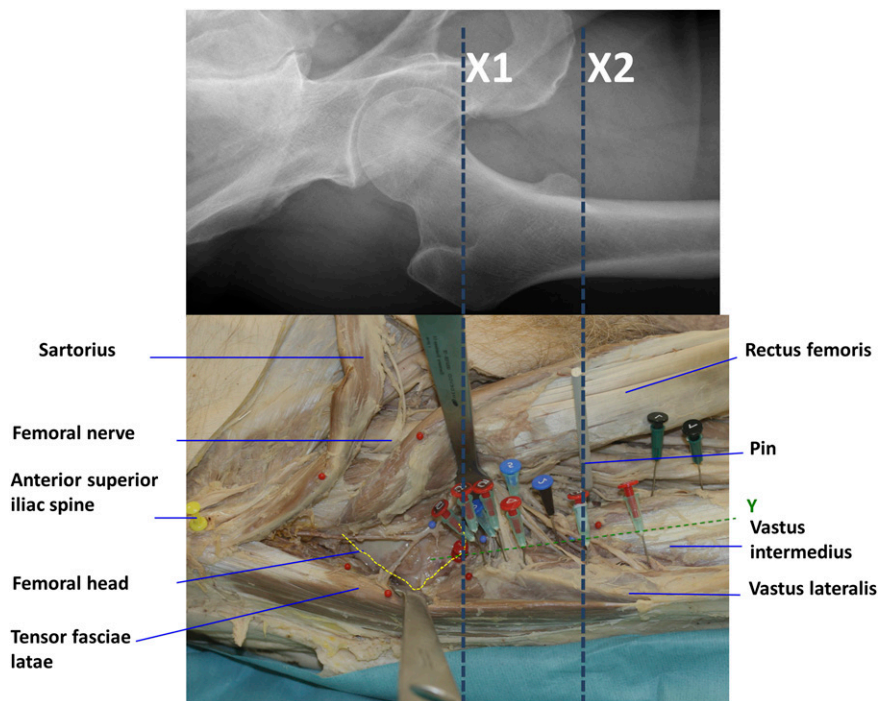


Fig. 1-B

Fig. 1-A Anterolateral view of the right hip. The anatomy of the anterior approach is presented. The internervous space between the sartorius and the rectus femoris medially and the tensor fascia femoris laterally is widened. The rectus femoris and sartorius are reflected medially. The yellow dotted line indicates the position of the skin incision slightly lateral to the anatomical plane. The yellow arrow indicates the way of access to the hip joint proximal to the nerve branches to the vastus lateralis and intermedius and the branches of the lateral femoral circumflex artery (LFCA). **Fig. 1-B** Anterolateral view of the right hip region (the same specimen as shown in Figure 1-A). Needles mark the entry points of the femoral nerve branches. Two Hohmann hooks are placed around the neck of the femur medially and laterally. The rectus femoris is reflected medially and the sartorius, proximally. X1 is a line through the middle of the neck of the femur on the level of the intertrochanteric line (red sticker), and X2 is the line through the lower margin of the lesser trochanter (pin, see also radiographic image). The green dotted line (Y) corresponds to the midline of the femur in a neutral position of rotation. The yellow dotted line indicates our preferred incision of the joint capsule during the standard anterior approach to the hip joint.

The purpose of this cadaver study was to demonstrate the neurovascular structures encountered during the direct anterior approach to the hip joint with special emphasis on potential distal extension or the placement of a cerclage cable passer around the proximal part of the femur.

Materials and Methods

Seventeen cadaveric hemipelves (ten paired and seven unpaired) from twelve specimens (eight male and four female) were investigated.

Seven limbs were “Thiel-fixed”¹⁴ and ten were embalmed in a formalin-based solution. None of the cadavers showed any evidence of previous trauma or surgery to the femur or hip joint. The dissection protocol began with each lower limb being placed supine on a dissection table and the hip joint approached anteriorly. For improved visualization, a 25-cm long incision following the anterior half of the iliac crest to the anterior superior iliac spine was made. From there, the incision was curved downward, aiming toward the fibular head. The superficial skin and subcutaneous tissue were removed. The fascia of the tensor fascia femoris muscle was incised laterally. Staying lateral to

the sartorius and rectus femoris muscles allowed us to identify the ascending branch of the lateral femoral circumflex artery where it entered the tensor fascia femoris muscle and trace it medially to its origin (Fig. 1-A). After resection of the joint capsule, the proximal margin of the muscle bellies of the vastus lateralis and vastus intermedius were localized at the intertrochanteric line. The femoral nerve was dissected proximal to the inguinal ligament, and its course was traced distally. The anterior approach to the hip joint was then extended distally along the anterior margin of the tensor muscle, while remaining lateral to the rectus femoris. All nerve branches to the vastus lateralis and vastus intermedius, the rectus, and the sartorius as well as the vessels arising from the lateral femoral circumflex artery were dissected carefully. To improve visualization of the neurovascular structures, the rectus femoris and the sartorius were transected distally and elevated medially and proximally. The tensor was mobilized from the underlying vastus lateralis. The entry point of each nerve branch into its specific muscle belly was recorded (Fig. 1-B), and the distances to two reference lines—X1 and X2, with distance X1 to X2 being 100%—were measured. X1 was the horizontal line through the middle of the neck of the femur just proximal to the intertrochanteric line, and X2 was the horizontal line through the lower margin of the lesser trochanter.

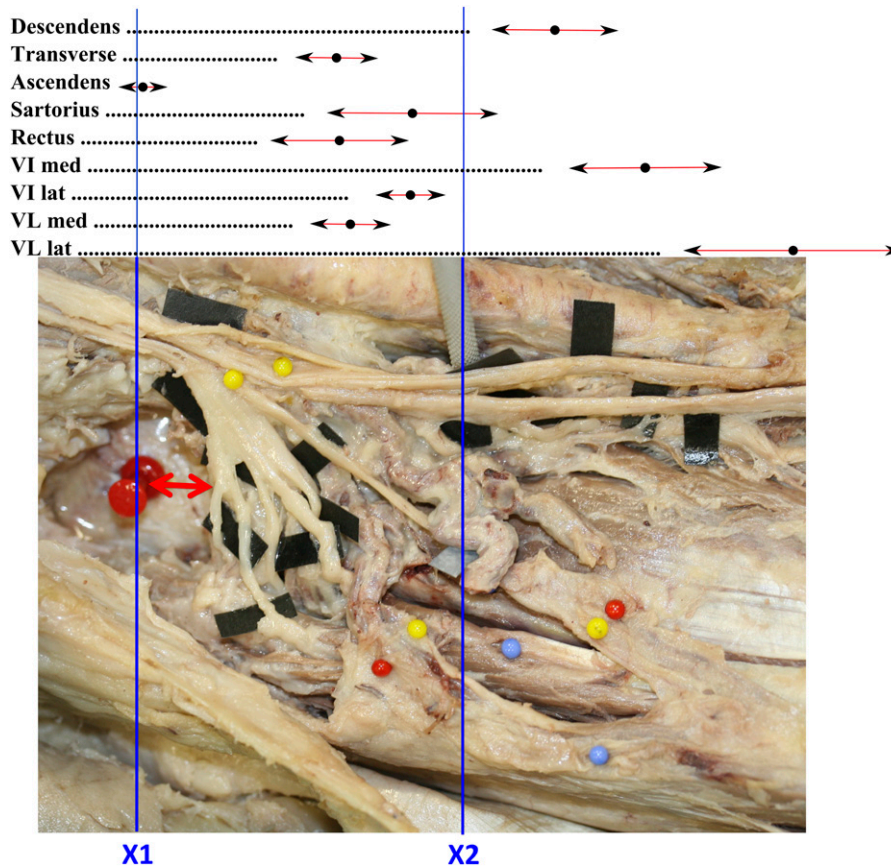


Fig. 2

The entry points (as a percentage of the distance from X1 to X2) of nerve branches into the lateral part of the vastus lateralis (VL lat), the medial part of vastus lateralis (VL med), the lateral part of the vastus intermedius (VI lat), the medial part of the vastus intermedius (VI med), the rectus femoris, and the sartorius in relation to lines X1 and X2. Ascendens, transverse, and descendens refer to the areas where the ascending, transverse, and descending branches of the lateral femoral circumflex artery cross the midline of the femur. For better visualization, some nerve branches are marked with black paper. X1 corresponds to the horizontal line through the middle of the neck of the femur just proximal to the intertrochanteric line, and X2 corresponds to the horizontal line through the lower margin of the lesser trochanter (distance X1 to X2 is 100%). Red double arrow = the shortest measured distance between the horizontal line X1 and the first entrance of a nerve branch, black dots in the centers of the double black arrows = the average distance, and black double arrows = 95% confidence limits.

The distances from the point where the vessels of the lateral femoral circumflex artery crossed the midline of the femur (Y) in a neutral position of rotation were also recorded. Nerve branches to the vastus lateralis and vastus intermedius were traced intramuscularly, and their courses deep into the muscle surface were studied. Finally, a cerclage cable passer (Stryker, Selzach, Switzerland) was placed around the shaft of the femur just distal to the lesser trochanter, and its proximity to the neurovascular structures was recorded. The cerclage cable passer was inserted once through the extended anterior approach and once through a separate lateral subvastus approach. Both passing methods were investigated as they were performed from medial to lateral and from lateral to medial.

Source of Funding

No external funding was used in this study.

Results

The distance from X1 and X2 to the points where the branches of the lateral femoral circumflex artery intersected the Y line and the distance from X1 and X2 to the points where the muscle branches of the femoral nerve entered the specific muscle belly are shown in Figure 2 as percentages (with the distance from X1 to X2 being 100%). The lateral femoral circumflex artery diverged into the ascending, transverse, and descending branches between the horizontal reference lines X1 and X2 in all cases. The ascending branch always progressed directly above the middle of the femoral neck, the transverse branch was always between reference lines X1 and X2, and the descending branch was below the reference lines.

The mean distance (and standard deviation) between X1 and the proximal nerve branches of the vastus lateralis or vastus intermedius was 34 ± 14.5 mm (range, 9 to 75 mm). In eight of the seventeen lower limbs, one or more nerve branches pierced

the vastus lateralis or vastus intermedius <20 mm distal to X1. The shortest measured distance in millimeters between the horizontal line X1 and the first entry point of a nerve branch of either the vastus lateralis or the vastus intermedius was 9 mm.

A vascular and nerve web of the lateral femoral circumflex artery and muscle branches of the femoral nerve coursed toward the muscle fibers of the vastus lateralis and vastus intermedius (Fig. 3). We found separate proximal-medial and distal-lateral muscle bellies of the vastus lateralis. These two muscle bellies, together with lateral portions of the vastus intermedius, were supplied by nerve branches from the same lateral division of the femoral nerve. The main nerve branch to the lateral part of the vastus lateralis coursed regularly together with the descending branch of the lateral femoral circumflex artery and vein. Additional neural supply was provided from the proximal aspect of the femoral nerve.

The blood supply to the vastus lateralis and vastus intermedius proximally was either via the transverse branch or ramifications of the ascending branch of the lateral femoral circumflex artery. The lateral part of the vastus intermedius received nerve branches from the same division of the femoral nerve that supplied the vastus lateralis. The medial part of the vastus intermedius was supplied by medial branches of the femoral nerve. Those branches supplied deep layers of the vastus intermedius, which served the articularis genus in the distal aspect. The rectus femoris and the sartorius were innervated by separate arcade-like branches of the femoral nerve that were more superficial and at a greater distance from the anterior border of the femur. Figure 2 shows the distribution pattern of the points of entry of nerves in relation to the anatomical reference lines X1 and X2.

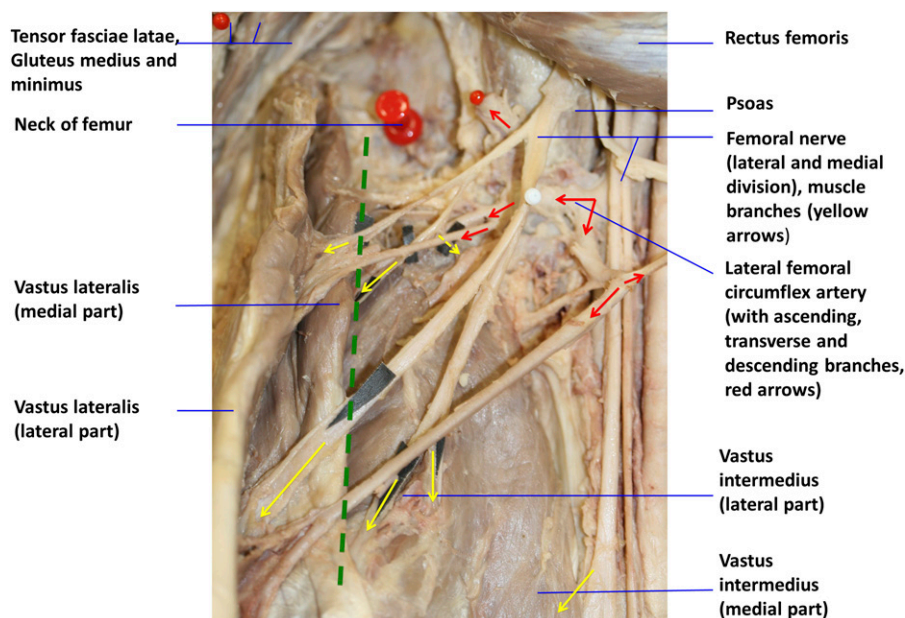


Fig. 3

Anterior view to the proximal part of the right thigh and the right hip joint. The sartorius (not visible) and rectus muscles are lifted proximally. For better visualization, some nerve branches (yellow arrows) are marked with black paper. The ascending branch of the lateral femoral circumflex artery and the joint capsule were partially removed. The green dotted line indicates the distal extension of the anterior approach to the hip joint. Neurovascular structures lateral to the incision are endangered, with the vastus lateralis and lateral portions of the vastus intermedius affected.

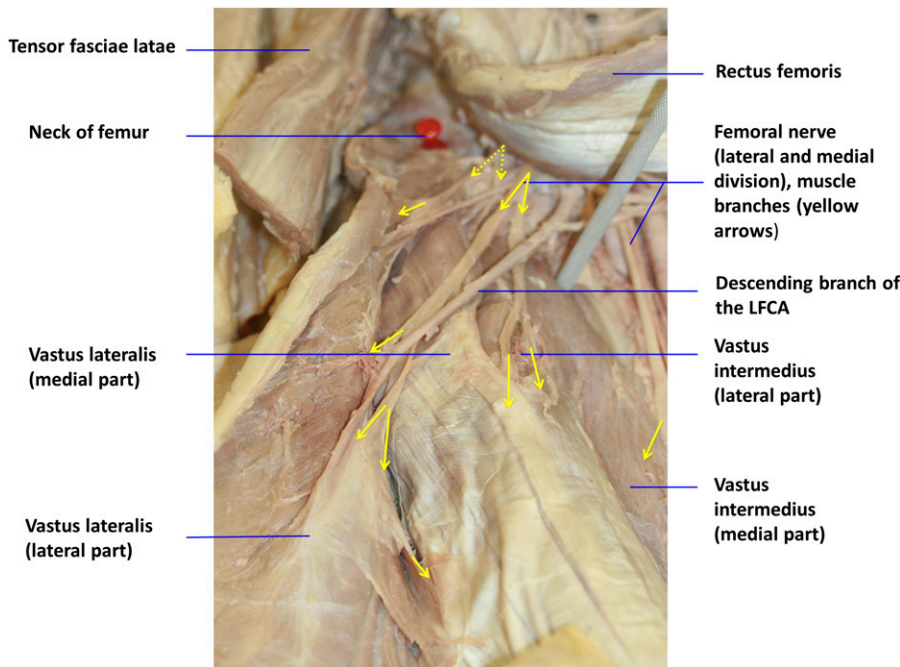


Fig. 4
Anterior view to the proximal part of the right thigh and the right hip joint (same specimen as shown in Figure 3). The sartorius (not visible) and rectus muscles are reflected proximally. The nerve branches (yellow arrows) extend between the individual muscle lamellae in a spiral-shaped manner around the femur distally and are then divided further dorsally into terminal branches. LFCA = lateral femoral circumflex artery.

Muscular portions of the vastus lateralis and vastus intermedius always joined dorsally in the direction of the linea aspera. In the deeper aspect, the nerve branches were divided; some extended to adjacent muscles. Further distally, terminal branches to the vastus intermedius also extended laterally, innervating the vastus lateralis dorsally. The intramuscular courses of the muscle branches had a specific pattern. The main branches extended between the individual muscle lamellae in a spiral-shaped manner around the femur distally, and they divided further dorsally into terminal branches (Fig. 4). The entry of nerve branches into muscles was always from the medial side in the anterior and superficial aspect of the muscles.

The introduction of a cerclage cable passer anteriorly, either from medial to lateral or vice versa, causes direct trauma to nerve branches supplying the vastus lateralis and the lateral portions of the vastus intermedius as well as to branches of the lateral femoral circumflex artery. It was impossible to introduce the cerclage cable passer around the femur without causing some damage to surrounding muscles. Introduction of the cable passer also jeopardized the deep femoral artery, the first perforating artery of the profunda femoris artery, and the lateral femoral circumflex artery. Intramuscular nerve branches to the vastus intermedius and the articularis genu were invariably injured. There was no damage to the nerves to the medial portions of the vastus intermedius or to the vastus medialis, rectus femoris, or sartorius.

When we introduced the cerclage cable passer through a lateral subvastus access, either from medial to lateral or vice versa, it was always possible to guide it close to the femur and protect important structures. No superficial nerves or large vessels were damaged. However, some nerve branches to deeper parts of the vastus intermedius, including the nerve branch to the articularis genu, were stretched by the instrument.

In all cases, extension of the anterior approach to the femur interrupted the nerve supply to the anterolateral por-

tions of the quadriceps muscle group (green dotted line on Figs. 3 and 5). Internally rotating the femur made it possible to turn some lateral nerve entry points away from the endangered

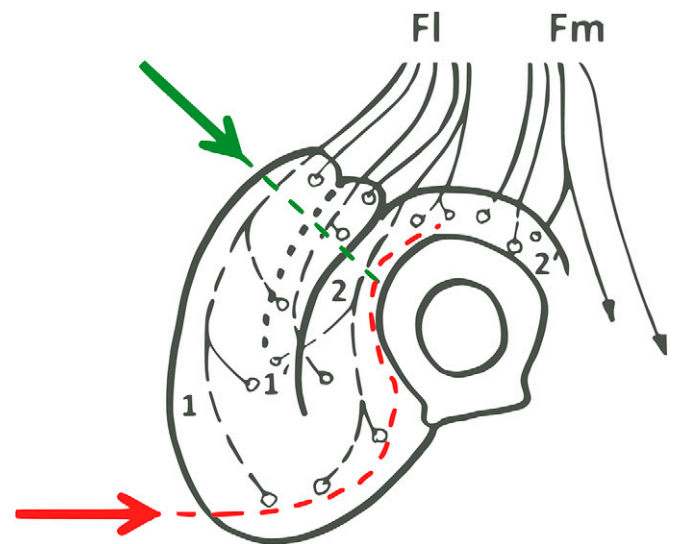


Fig. 5
Drawing illustrating the consequences of approaching the femur through an anterior approach (green arrow) compared with a lateral subvastus approach (red arrow). Extension of the anterior approach to the femur interrupts the nerve supply to the anterolateral portions of the quadriceps muscle group. When the lateral subvastus approach is used, the muscles and their anterior and superficial entering nerves can be protected. Fl and Fm = lateral and medial divisions of the femoral nerve, 1 and 1' = lateral and medial parts of the vastus lateralis, and 2 and 2' = lateral and medial parts of the vastus intermedius.

zone. Vessels leading to and away from the femur were also injured by the extension of the direct anterior approach. Further mobilization of the incised muscles would have strained deep muscular nerve branches and vessels.

Discussion

The direct anterior approach is a true internervous approach to the hip and has been used successfully by many authors¹⁻⁶. However, some have reported increased complication rates^{7,11,12,15}, such as intraoperative trochanteric fractures, femoral fractures, and perforations of the femur. Such complications may require distal extension of the approach, which also may be required with arthroplasty revision surgery. Extension of the anterior approach by splitting the interval between the rectus femoris and the vastus lateralis has been described^{1,13,16}. The present study shows that carrying out this extension without substantially damaging the lateral portions of the quadriceps muscles is challenging. Neurovascular structures lateral to the incision are endangered *directly*, affecting the vastus lateralis and lateral portions of the vastus intermedius. Deeper muscle branches and vessels are strained *indirectly* due to mobilization of muscles when the surgeon accesses the femur.

Patil et al. investigated the innervation pattern of the vastus lateralis muscle¹⁷, and their findings were in agreement with those of the present study. Splitting the vastus lateralis in the mid-lateral line of the femur resulted in denervation of the posterior half of the muscle. Splitting the underlying vastus intermedius in the same plane caused damage to the nerve supplying the vastus intermedius in most cases¹⁷. The vastus lateralis is the largest of the four quadriceps muscles, so damage to the vastus lateralis and the vastus intermedius theoretically reduces maximal quadriceps strength. However, Kennon et al. routinely used the direct anterior approach for revision surgery and suggested that this approach could be readily extended proximally and distally in complex revision cases, including stem revisions and even total femoral replacement¹. In a series of 468 consecutive revision total hip arthroplasties with distal extension, they split the vastus lateralis longitudinally in line with the skin incision and used a subperiosteal dissection to access the entire femoral shaft. They reported no clinically relevant nerve injuries. This may well be due to the fact that the distal portions of the vastus lateralis are supplied by nerve branches from the vastus intermedius and are not affected by extension to the proximal part of the femur. Furthermore, loss of some function of the vastus lateralis and the lateral part of the vastus intermedius can possibly be compensated for by the remaining portions of the quadriceps in low-demand patients. The present study shows that distal extension of the direct anterior approach is difficult to perform without causing neural damage to the proximal portions of the vastus lateralis and vastus intermedius. Alternative approaches for complex stem revisions should be considered.

The anterior access is also not ideal for the introduction of a cerclage cable passer at the proximal part of the femur for treatment of an intraoperative fissure or fracture. In this situation, a lateral subvastus approach seems more suitable and less damaging

to muscle. Whether this requires a separate skin incision depends on the selection and extension of the primary incision.

The present study highlights that the zone immediately distal to the intertrochanteric line is crucial. The first entries of nerve branches into muscles occur as close as 9 mm distal to the intertrochanteric line. The zone defines an anatomical barrier and should not be crossed distally unnecessarily.

The ascending branch of the lateral femoral circumflex artery consistently lies at the level of the midpart of the femoral neck, which is an important consideration in open or arthroscopic surgery in the anterior aspect of the hip joint. The branches of the lateral femoral circumflex artery are substantially involved in the vascularization of the proximal quadriceps muscle group.

In conclusion, the present cadaver study indicated that distal extension of the direct anterior approach to the hip joint is difficult to perform without causing neurovascular injury to anterolateral parts of the quadriceps muscle group. The direct anterior approach to the hip joint is best suited for interventions proximal to the intertrochanteric line, such as primary hip replacement, treatment of femoral head fractures, revisions of the acetabulum, and simple femoral stem revisions. An alternative approach to the hip or an extended trochanteric osteotomy should be considered for complex stem revisions necessitating distal extension. When the direct anterior approach must be extended distally, a lateral subvastus access seems more advantageous. ■

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